WATER CYCLE AND CLIMATE EXTREMES MODELING

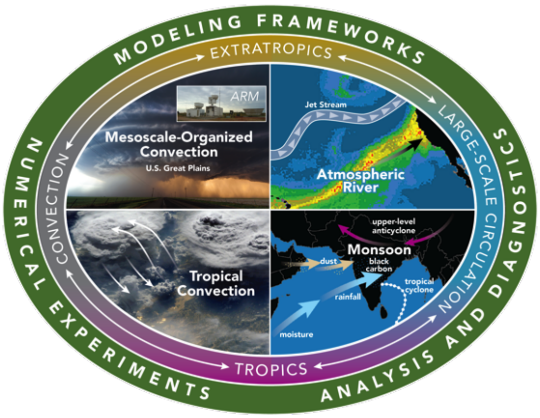
Clouds and convection play a key role in regulating the Earth's energy and water cycles and modulating the regional and large-scale meteorological context for extreme events. By addressing science questions at the intersection of clouds, convection, and atmospheric circulation, the Water Cycle and Climate Extremes Modeling (WACCEM) scientific focus area is advancing predictive understanding of water cycle processes and their subseasonal-to-multidecadal variations and changes.

Through foundational research using models, observations, and novel numerical experiments and analysis methods, the goal of WACCEM is to improve predictability of water availability and understanding societal vulnerability to extreme hydrologic events.

WACCEM is organized around three overarching science questions:

1. How do large-scale circulation features modulate regional mean and extreme precipitation, and how will they change in the future?
2. What processes control mesoscale convection and associated warm season regional mean and extreme precipitation and how will they change in the future?
3. How do atmospheric circulation features and water cycle processes interact across scales, and how do they influence regional precipitation and its extremes?

Guided by these questions, WACCEM's research is encapsulated in three research elements.



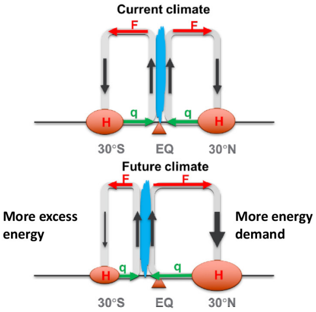
1. LARGE-SCALE CIRCULATION

The monsoon-Intertropical Convergence Zone (ITCZ) are large-scale circulation systems that have global significance in terms of their impacts on energy and water cycles. Observations and modeling have indicated changes in the monsoon-ITCZ system in the past and future, but scientists' understanding of the mechanisms controlling the mean and variability of the system is insufficient to predict its behavior across a range of scales and how it might respond to external climate forcings.

In the extratropics, a recently discovered subseasonal mode of variability, called the baroclinic annular mode (BAM), offers a potential source of predictability for intraseasonal variability in wind, temperature, and precipitation in the midlatitudes. However, lacking an understanding of the BAM manifestation and implications in the synoptic evolution of weather events limits scientists' ability to exploit the potential source of subseasonal predictability.

These topics of research will be explored, with the objectives to:

- gain a better understanding of the mechanisms, such as the role of cloud radiative processes and energy transport pathways linking the ocean forcing to the monsoon, controlling the monsoon-ITCZ response to forcings, and



WACCEM scientists provided the theoretical underpinning for the seasonal delay in monsoon precipitation under warming projected by an ensemble of earth system models, with important implications for crops and water resources planning in monsoon regions around the world.

- develop a connection between the BAM and the evolution of weather events and extremes and understand the driving mechanisms for the enhancement of the BAM variability under warming.

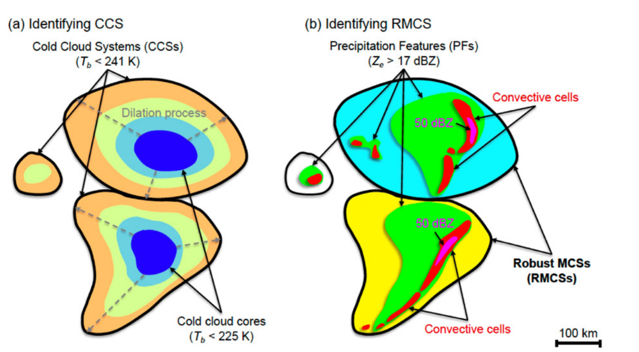
2. MESOSCALE CONVECTION

Mesoscale convective systems (MCSs) are ubiquitous in the global tropics and extratropics, with important effects on large-scale circulation, precipitation, and hydrologic floods. Although MCSs have been widely studied in the context of severe weather forecast, there is much less understanding of MCSs in the climate and hydrological context.

This is partly due to the lack of in situ measurements over the tropical oceans and in many regions over land, limiting the ability to characterize MCSs and their large-scale environments. As MCSs exhibit precipitation characteristics rather distinct from isolated storms, their variability and trends can have important implications for the surface water balance and hydrologic floods.

This element aims to:

- characterize MCSs and their large-scale environments from the global tropics to the extratropics to understand their role in the climate system and potential changes in response to forcing; and
- characterize the surface water balance and hydrologic floods associated with MCSs in the United States to advance an understanding of their role in surface hydrology and precipitation recycling.



WACCEM developed the FLEXTRKR algorithm that is being used to characterize MCSs globally using satellite data and high-resolution modeling with data assimilation.

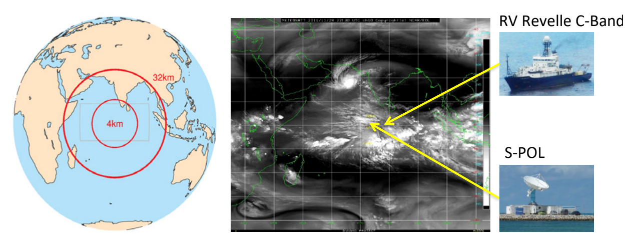
3. MULTISCALE INTERACTIONS BETWEEN CONVECTION AND LARGE-SCALE CIRCULATION

Predicting monsoon rainfall is challenging because scientists lack an understanding of how convection interacts with the multiscale monsoonal overturning circulations that produce precipitation across a range of temporal and spatial scales. Interactions between convection and atmospheric circulation also have important implications for understanding subseasonal variability of monsoon active and break periods and extreme events such as atmospheric rivers (ARs) and tropical cyclones (TCs), which are known to be modulated by the Madden Julian Oscillation (MJO).

Propagation of the MJO to the Maritime Continent (MC) induces Rossby wave trains that influence extratropical weather, but scientists lack an understanding of what controls the propagation of the MJO in the Indo-Pacific MC. There is also a lack of understanding of the processes by which the MJO affects TCs.

This element aims to:

- quantify the role of shallow, deep, and organized convection in atmospheric overturning circulation and precipitation in Asian and African monsoon systems; and
- advance understanding of what controls the propagation of the MJO in the Indo-Pacific MC and how the MJO influences extreme events such as ARs and TCs.



Convection permitting simulations and observations of an MJO event during the DYNAMO field campaign were used to understand large-scale precipitation variability and extremes.

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Project Website
http://climatemodeling.science.energy.gov/projects/water-cycle-and-climate-extremes-modeling